OPEN GRADED FRICTION COURSE USAGE GUIDE

California Department of Transportation
Division of Engineering Services
Materials Engineering and Testing Services-MS #5
Office of Flexible Pavement Materials
5900 Folsom Boulevard
Sacramento, CA 95819-4612

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

The Open Graded Friction Course Usage Guide is intended for use by California Department of Transportation (Caltrans) Design, Construction, and Maintenance Managers and Engineers, as well as by field personnel involved in placement of open graded friction course (OGFC). The purpose of this Guide is to:

- Provide an overview of OGFC and the benefits and limitations of this material;
- Describe the various types of OGFC and present criteria for selection and use; and
- Provide state-of-the-practice information regarding design, materials and mix design criteria, production and placement, and acceptance testing of OGFC.

An electronic copy of this Usage Guide can be found on the Internet at:
http://www.dot.ca.gov/hq/esc/Translab/fpmpubs2.htm

DISCLAIMER

Development of this Guide was sponsored by Caltrans Pavement Program Steering Committee, and developed through the Caltrans/Industry Asphalt Concrete Task Group. The contents of this Guide reflect the views and experience of the authors, who are responsible for the facts and accuracy of the information presented herein. This Guide does not constitute a standard, specification or a regulation.

1.0 INTRODUCTION AND OVERVIEW

The purpose of the Open Graded Friction Course Usage Guide is to provide the California Department of Transportation (Caltrans) with an overview of open graded friction course (OGFC), its benefits and limitations, product selection and use, and state-of-the-art information regarding design, materials and mix design criteria, production and placement, and acceptance testing. It contains generally accepted best practices to optimize OGFC performance.

1.1 HISTORY OF DEVELOPMENT

The initial interest in open graded hot mix grew out of efforts to avoid the shortcomings of chip seal construction, which include broken windshields from loose aggregates and time constraint problems associated with setting aggregates during a sudden rainstorm. Over time, it has become recognized as a solution to reduce the dangers of hydroplaning and poor visibility caused by splash and spray.

In the 1930's, Oregon began experimenting with open graded surface courses to improve skid resistance. Initially, the surface adopted as the standard had a maximum aggregate size of ½ inch and was laid at a minimum thickness of ¾ inch on a dense impermeable base. However, Oregon encountered problems associated with durability, draindown and rich spots, and they were forced to slow its usage. In the 1980's, Oregon accelerated the use of open graded mixes and perfected its use. As of 2005, the type of OGFC used 90 percent of the time in Oregon is their "Type-F" mix. The Type F mix uses larger aggregate (1 to 1½ inch maximum size) and 100 percent crushed aggregate to build a coarser and thicker surface course that has a large number of voids. The Type F mix is used in areas of heavy and frequent precipitation within Oregon.

Substantial use of the open graded mix began in the Western states around the late 1940's. The aggregates employed were essentially the same as that used in normal chip seals (⅜ inch maximum size). They were mixed with a relatively high percentage of paving-grade asphalt in a hot mix plant and paved at a thickness of ⅝ inch to ¾ inch. As early as 1944, California began using this type of construction as drainage interlayers and as an alternative to chip seals and slurry seals. With continuous refinement, Caltrans has utilized OGFC, which is also referred to as open graded asphalt concrete (OGAC), with varying gradations and asphalt binder types with a significant amount of success.

1.2 WHAT IS OPEN GRADED FRICTION COURSE?

An OGFC is a sacrificial wearing course. OGFC consists of an aggregate with relatively uniform grading and little or no fine aggregate and mineral filler. It is designed to have a large number of void spaces in the compacted mix [as compared to dense graded asphalt concrete (DGAC)].

1.3 BENEFITS OF OPEN GRADED FRICTION COURSE

The most important benefit of OGFC is the increase in roadway safety during wet weather by providing maximum tire to surface contact and strong contrast in pavement markings. Studies have shown that its open void structure aids in the drainage of water and preservation of the surface friction. Once water contacts the OGFC surface, the void structure allows it to drain below the contact point between the tire and pavement to reduce the potential for hydroplaning and splash and spray. Thus, it reduces skid and hydroplaning-related accidents.

1.4 HOW IS OPEN GRADED FRICTION COURSE USED?

OGFC can be used in new construction, major rehabilitation projects, and maintenance overlays. It is normally used as a sacrificial wearing course over DGAC pavement in areas that experience high traffic volumes and moderate to heavy rainfall.

Although OGFC is typically used to overlay DGAC pavement, Caltrans has placed rubberized OGFC (rubberized OGFC is referred to as RAC-O and RAC-O-HB) in a relatively thin layer on portland cement concrete pavement (PCCP) in pilot projects, and Arizona routinely overlays their PCCP with rubberized OGFC. To date, the pilot projects are performing successfully. Research in the area of composite pavements is on-going, and the District Materials Engineer should be consulted before planning to overlay PCCP with RAC-O and RAC-O-HB.

OGFC can renew existing surfaces in terms of functional performance (i.e., ride quality). When OGFC overlays are used as wearing courses and are placed on structurally sound pavements, they can rectify/retard the following distresses:

- Raveling
- Oxidation
- Skid Problems
- Hydroplaning
- Splash and Spray
- Flushing and Bleeding
- Reflective Cracking (only for RAC-O and RAC-O-HB)

1.5 WHERE SHOULD OPEN GRADED FRICTION COURSE BE USED?

The following are specific situations where the use of OGFC should be considered:

- Hydroplaning: Consider OGFC when the Traffic Accident Surveillance and Analysis System (TASAS) Report reveals a high percentile confidence level for wet accidents or when Traffic Safety recommends the use of OGFC to minimize wet accident occurrences. It will minimize hydroplaning potential during rainstorms by providing drainage channels for water to flow beneath the pavement surface. As a result, good tire-pavement contact can still be maintained in the presence of water.

- Wet and Nighttime Visibility: Consider OGFC when the TASAS Report reveals a high percentile confidence level for wet and nighttime accident occurrences. It will minimize splash and spray due to rain by allowing water to be forced downward into the channels of the OGFC. With less surface water and glare at night during wet weather, reflected light from oncoming vehicles can mostly be dispersed by the angularity of the OGFC structure. As a result, better visibility of traffic stripes can be obtained with headlights reflected back to the driver in a more desirable manner.

- Skid Resistance: Consider OGFC when a higher friction number is required to provide safety for high speed driving during wet weather. With the unique macrotexture (aggregate grading and void structure) of the OGFC, the friction numbers do not decrease as rapidly with increasing speed as they do with DGAC. As a result, both OGFC and DGAC surfaces may have similar friction numbers when measured at medium speed, but the friction numbers of OGFC at high speed will be significantly higher than that of DGAC.

- Location: OGFC should be used when a project is located adjacent to pavement with existing OGFC (e.g., a new lane widening) to maintain continuity of the pavement cross section and slope. This will prevent creation of a dam or bathtub effect that can trap water in the existing OGFC. OGFC can also be used in locations where chip seals are prohibited due to traffic volume.

- Cross Slope: Consider OGFC when the cross slope is less than 2 percent and there are two or more lanes in one direction. Although it is extremely effective in removing water from the pavement surface, it should not be deemed as the solution for correcting cross slopes.

- Roadway Smoothness: Consider OGFC as an alternative to chip seals and slurry seals when correcting minor surface irregularities. It should be noted that OGFC must not be used to correct severe rutting or depressions in the underlying pavement. Such use could create a basin, which will allow accumulated water to seep into the base and accelerate pavement structural damage. Existing pavements with rutting and depressions must be leveled with DGAC prior to overlaying with OGFC.

- Oxidation Reduction: Consider OGFC in the desert areas as a protective and sacrificial layer to delay or prevent asphalt from aging the DGAC structural section layers.

- Mitigation of Flushing and Bleeding: Consider OGFC as a maintenance overlay to temporarily mitigate flushing and bleeding. Its open void structure increases the pavement friction in these areas and allows absorption of free surface asphalt to overcome bleeding pavements. It should be noted that this may only provide a short term solution and may not prevent rutting or completely address the source of the distress.

1.6 WHERE SHOULD OPEN GRADED FRICTION COURSE NOT BE USED?

In general, OGFC should not be used on:

- Unsound Pavements: OGFC should never be used directly over structurally inadequate pavements without properly preparing the existing pavement. Pavement distress should be addressed prior to applying OGFC (see Section 2.2.2 of this Guide). The extent of pavement distress precluding the use of OGFC has not been quantified at this time.

- Snow or Icy Areas: In snow or icy areas where tire chains, studded tires, or snowplows are commonly used, OGFC has exhibited raveling distress. However, this condition may be mitigated by the use of modified binders.

- Areas with Severe Turning Movements: Areas that experience short radius turning are not recommended for placement of OGFC. These areas include parking areas, intersections, ramp terminals, truck stops and weigh stations.

- Muddy and Sandy Areas: OGFC should not be used in areas where mud or sand may be tracked onto the pavement from unsurfaced side roads (roadways that experience significant agricultural traffic or near beaches and sand dunes). The fines from mud and sand can fill the voids and reduce the drainage capacity of the OGFC.

- Areas Prone to Oil and Fuel Dripping: OGFC should not be used in areas where dripping of oil or fuel from slow or stopped vehicles could cause the surface to soften and deteriorate rapidly. These areas include intersections.

- Bridge Decks: OGFC should not be used to overlay a bridge deck without special approval from Headquarters Structures Design and the District Materials Engineer.

- Digouts and Localized Areas to be Removed and Replaced: OGFC should not be placed in areas where a bathtub effect may be created. When sections of DGAC pavement are removed, DGAC should be used as a replacement material before overlaying with OGFC.

- Cold Climatic Areas: OGFC should not be placed in cold weather (< 45ºF). OGFC with polymer modified binder must be used when the atmospheric temperature is between 45ºF and 55ºF or when the minimum mix laydown temperature can not be achieved with conventional (unmodified) binders (see Table 1 and Table 2).

1.7 NOISE CONSIDERATIONS

Generally, test results have indicated that open graded mixes are typically 3-5 dBA quieter than DGAC pavements. Through limited testing, Caltrans has not found any significant difference in noise reduction between conventional and rubberized OGFC pavements.

Federal and state agencies are currently working on substantiating and quantifying the noise reduction benefit of OGFC over time. Limited studies to date have indicated that noise levels on OGFC pavements will increase about 1 dBA every 3 years. Until on-going research is complete, the potential benefit of noise mitigation should not be the reason for constructing OGFC pavements. Noise related issues within Caltrans should be referred to the Pavement Standards Team (PST).

1.8 COST CONSIDERATIONS

In general, OGFC should not be used as a routine surface seal when a life cycle cost comparison shows significant cost savings from other surface seal treatments such as a chip seal or slurry seal. The user should cost out alternatives with respect to expected life and the distress modes addressed.

OGFC is more expensive per ton than DGAC, but the unit weight of the mix in-place is lower, which partially offsets this higher cost. Costs will vary with the use of modifiers (polymer and asphalt rubber), thickness of the overlay and expected life under the conditions in which it is used. Using modified asphalt binders tends to increase the life expectancy of OGFC.

The following Caltrans Website contains cost data for OGFC with various binder types:
http://www.dot.ca.gov/hq/esc/oe/awards/

1.9 ALTERNATIVE TO OPEN GRADED FRICTION COURSE

The use of the bonded wearing course (BWC) is currently being studied by Caltrans. BWC is similar to OGFC in terms of its attributes and benefits, including the reduction in hydroplaning and splash and spray. Caltrans constructed BWC pilot projects in 2005 on Interstate 5 in District 10 and on State Route 99 in District 6. More information about these projects can be found on the Internet at:

> http://www.dot.ca.gov/hq/maint/TAGBondedWearingPilotProjects.pdf

2.0 OPEN GRADED FRICTION COURSE MATERIALS AND DESIGN

2.1 MATERIAL SELECTION

Caltrans requirements for aggregate gradation and quality are listed in the Standard Specifications and Standard Special Provisions (SSPs). It has been found that coarser aggregate gradations gives a more open void structure and increases deformation resistance.

2.1.1 *Coarse Aggregate Selection*

The physical properties of the coarse aggregate in OGFC are critical in attaining a high friction number and maintaining a low gradient for friction number versus speed. Pavement skid resistance is a function not only of the large-scale texture (macrotexture), but also of the small-scale texture (microtexture).

In DGAC, while the macrotexture is provided by the coarse aggregate, microtexture is provided by both the coarse and fine aggregates. In OGFC, with limited amount of fine aggregate, macrotexture and microtexture are provided by the coarse aggregate. It is important that this characteristic be considered in the selection of coarse aggregate to delay material deformation, which closes void structure and reduces macrotexture. To preclude premature deformation, aggregates selected should be coarse, hard, angular and abrasion resistant to provide ample stone-on-stone contact, high deformation resistance and low susceptibility to clogging.

2.1.2 *Aggregate Gradation*

The attainment of the desired pavement macrotexture and internal drainage characteristics is primarily a function of the aggregate gradation in the OGFC mixture. Most of the United States uses a nominal maximum aggregate size of ⅜ inch. Caltrans allows ⅜ inch and ½ inch gradations for OGFC as specified in the Standard Specifications. In addition, with the approval of District Material Engineers, a 1-inch gradation (similar to the Oregon Type F mix) may be allowed in areas with an abnormally large demand for drainage capacity.

2.1.3 *Asphalt Binder Selection*

Since OGFC has a high percentage of voids accessible to air and water penetration, many states use softer binder to increase durability by prolonging the time for the binder to age-harden (oxidize). On the other hand, other states use harder binder to permit higher mixing temperature and viscosity; thus, increasing film thickness to resist age-hardening. While the softer binder is most effective in areas subject to severe winters, harder binder has been found most useful in states subject to high pavement temperatures in the summer and relatively mild temperatures in the winter.

Caltrans currently uses unmodified performance graded (PG) asphalt binders and also polymer and asphalt rubber modified binders in OGFC. In general, an appropriate unmodified PG binder is used in normal applications and modified binders are used for cold temperature placement in areas with cooler climates or thermal cracking problems.

Durability is a function of initial binder viscosity and film thickness. With elastomeric properties to resist flow at high production and service temperatures, modified binders increase the amount of asphalt binder that can be used in open-graded mixes without experiencing binder draindown. Thicker asphalt film thickness improves OGFC durability and performance. To improve abrasion resistance, delay aging, and resist thermal cracking, Caltrans uses PBA 6a and PBA 6b binders in cold climatic conditions (e.g., nighttime paving and paving near coastal or desert areas).

Asphalt rubber open graded mixes (RAC-O and RAC-O-HB) are less susceptible to temperature, and have a thick asphalt film thickness-which is good in resisting fatigue and reflective cracking. However, they have not performed well in areas with severe turning movements, e.g., in parking areas.

RAC-O mixes with higher binder contents are referred to as RAC-O-HB. These mixes are very durable; however, the increased binder content in RAC-O-HB can plug air voids and affect its ability to reduce splash and spray and decrease hydroplaning.

To control the extra cost associated with the production of RAC-O and RAC-O-HB, Caltrans currently allows each region/district to establish its own minimum rubberized OGFC job size. For more information on RAC-O and RAC-O-HB mixes, refer to the "Asphalt Rubber Usage Guide" located on the Caltrans Website at:

> http://www.dot.ca.gov/hq/esc/Translab/metspubs.htm

2.2 Structural Design Considerations

Selection of an OGFC should take into account factors such as traffic level and speed, prevalent accident frequency and type, snow and ice accumulation, rainfall frequency and intensity, roadway alignment, and skid resistance of the existing pavement. In addition, atmospheric temperatures during placement and service life need to be considered during design to ensure that the proper type of OGFC is specified (see Table 1 and Table 2).

In general, OGFC pavement is constructed when there is a safety concern in wet weather driving to reduce tire splash and spray, provide better skid resistance and lessen hydroplaning potential. It will help retard raveling from DGAC pavements that have an asphalt deficiency and it has a longer life than chip seals. In some high elevation areas, it does not perform well in snow areas due to freeze thaw conditions and snow removal equipment. Parking areas, intersections and truck stops are not recommended for OGFC (see Section 1.6). OGFC made with polymer modified binder and asphalt rubber may retard most reflective cracks that are less than ¼ inch wide but will not prevent reflective cracking in alligator (fatigue) cracked pavements.

In addition, the use of OGFC for Long Life Pavements in urban freeway areas may be beneficial in minimizing future construction needs by serving as a sacrificial layer to protect and extend the useful life of the underlying pavement layers. The strategy is that on these Long Life Pavements, only the OGFC layer will need to be periodically removed and replaced and the layers below will not need as much maintenance or repair.

2.2.1 *Structural Support*

Although Caltrans has assigned a gravel factor of 1.4 to OGFC, Caltrans does not currently consider its structural benefits when determining layer thicknesses for pavement structural sections. In general, OGFC is considered as a sacrificial surface course designed primarily to extract water and secondarily to extend the service life of the underlying DGAC pavement by slowing age-hardening of the asphalt binder.

OGFC should never be used directly over structurally inadequate pavements without properly preparing the existing pavement. Furthermore, existing OGFC surfaces should be removed by milling or cold planing prior to placing surface treatments or hot mix asphalt overlays for several reasons, including:

- An overlay or surface treatment may seal moisture in the OGFC. The moisture may lead to stripping.
- The high air voids (approximately 18 to 20 percent) in OGFC will create a weak layer in the pavement structural section to be overlayed. The weak layer may be within the tensile zone of the pavement structure.

OGFC is more susceptible to fatigue cracking due to reduced tensile strength of the mix.
- OGFC, over a period of time, may partially fill with fines. Removing the OGFC will provide a clean surface to pave on.

However, contrary to national experience, a 1999 study conducted by Caltrans District 1 has shown that OGFC can be successfully overlayed with both OGFC and DGAC without removing it if the OGFC mix was properly constructed, its surface did not exhibit any distress, and the OGFC daylights at each edge of pavement. Of the 30 cores taken in a 3 county study, only 2 cores exhibited minor to moderate stripping. The study was done at locations with annual precipitation ranges from 29 inches to 66 inches.

Based on this 1999 Study, second thought is being given to overlaying OGFC with OGFC. Although not recommended in this Guide, OGFC may be placed over an older OGFC pavement with the approval of the District Materials Engineer and only if the older OGFC pavement was placed from edge of pavement to edge of pavement. It is not recommended to overlay OGFC a third time.

Without approval from the District Material Engineer, overlaying OGFC with DGAC is not permitted.

2.2.2 *Surface Preparation*

OGFC should be placed on a structurally sound pavement with minimal cracks and rutting. Substantial cracking in the underlying pavement may reflect through the OGFC and rutting may cause water to pond, leading to separation of the OGFC from the underlying pavement. Increasing the thickness of an OGFC layer to cover up a moderately or seriously distressed pavement is not a good practice. Because the amount of cracking or rutting that precludes the use of OGFC has not been quantified, removal by cold planing and/or repair of cracks and ruts should be based on past experience and criticality of locations.

Cold planing can be expensive. In the year 2000, without accounting for traffic control costs, cold planing was estimated to cost \$11/yd^2. However, not cold planing an existing failed surface prior to placing OGFC can results in a much higher expense if the OGFC traps water and the pavement structural section is damaged and needs to be removed and replaced. The removal and disposal of pavement grindings and thermoplastic markings should conform to current standards and policies.

All cracks and joints ¼” wide or wider in the DGAC surface should be sealed prior to placing OGFC.

2.2.3 *Edge Location*

It is recommended to place OGFC from edge of pavement to edge of pavement to provide a cross-section with uniform frictional properties and appearance and a foundation for possible future OGFC overlays (see Section 2.2.1). As a minimum, OGFC should extend 3 feet beyond the traveled way onto each shoulder.

One possible problem identified with paving OGFC from edge of pavement to edge of pavement to accommodate future overlays is that OGFC slowly silts up in places where traffic is not intense. This problem, therefore, does not occur in the traveled way, but the real problem is with the shoulders. Since the shoulders do not experience traffic, they may clog and impede drainage from the traffic lanes.

2.2.4 *Grading and Minimum Thickness Requirement*

The ½ inch OGFC is typically used Statewide and is appropriate for most applications with a minimum lift thickness of 0.10-foot (the most common OGFC lift thickness used by Caltrans). For lift thicknesses less than 0.10-foot, the ⅜ inch OGFC should be specified.

In some instance, thicker layers of OGFC (up to 0.15-foot) are placed in outer lanes to aid in the lateral movement of water from the traveled way and provide better skid resistance. This is especially true for multi-lane roadways with a long steep slope or an unusual superelevation.

In areas where the ½ inch OGFC is prone to plugging, a special 1-inch aggregate gradation (similar to the Oregon Type F mix) can be placed in a minimum lift thickness of 0.17-foot and a maximum lift thickness of 0.25-foot.

2.2.5 *Grading and Minimum Atmospheric Temperature Requirement*

In general, the ⅜ inch and ½ inch aggregate gradations are used in locations with atmospheric temperatures greater than 70°F during placement. For atmospheric temperatures 70°F or below during placement, Caltrans requires a ½ inch or 1-inch aggregate gradation and specifies the minimum thickness requirement in the Standard Specifications and SSPs. In addition, polymer modified binder is required when the atmospheric temperature is less than or equal to 55°F (but greater than 45°F) during placement to allow for thicker asphalt film thicknesses and higher paving temperatures without as much concern for draindown, thus allowing more time to achieve compaction.

2.3 MIX DESIGN CONSIDERATIONS

The following are mix design considerations.

2.3.1 *Asphalt Content*

In most states, the method of selecting the asphalt content consists of two steps. It begins with measuring the surface capacity of the coarse aggregate, K_c, and it ends with calculating the asphalt content by use of an equation based on field experience with similar graded mixtures. In Caltrans, the asphalt content is determined during the mix design in conformance with the requirements in California Test 368.

2.3.2 *Void Capacity of Coarse Aggregate*

The coarse aggregate used in the OGFC mixture must provide enough room for the required asphalt binder content and interconnected voids needed for drainage. After the final compaction, it should have adequate void capacity to allow for the lateral movement of water during rainstorms. In most states, the design void capacity is around 18 percent. Studies have shown that design voids of appreciably less than 15 percent result in surfaces that do not maintain optimum water drainage. OGFC mixes in Caltrans are not designed to a minimum air voids content. However, California Test 368 provides adequate air voids in OGFC mixes based on empirical data.

2.3.3 Optimum Fine Aggregate Content

The optimum amount of fine aggregate is that which fills the voids between the coarse aggregate particles without bulking the coarse aggregate. In most states, including California, the fine aggregate fraction passing the No. 4 sieve is limited to approximately 15 percent by volume of the total aggregate.

2.3.4 *Optimum Mixing Temperature*

The mixing temperature is based on the concept that aggregate should be adequately heated to accept coating and adhesion, but not to the point of asphalt draindown or segregation during transit from the mixing plant to the jobsite. In Caltrans, the mixing temperature of the OGFC mixture is specified in the Standard Specifications and SSPs.

2.3.5 *Resistance to Effects of Water*

Since the interior of OGFC is accessible to water, a number of states require the use of anti-strips (liquid or lime) in the mixture as a standard practice in preventing moisture damage. Studies have shown that anti-strips can also counteract the tendency of asphalt to draindown during transit. In Caltrans, requirements to treat OGFC mixes with anti-strips are currently determined by the District Material Engineers.

3.0 OPEN GRADED FRICTION COURSE PRODUCTION AND CONSTRUCTION

The production and construction methods of OGFC are similar to that of DGAC. The following are special notes and exceptions.

3.1 PRODUCTION

No specific modifications are required to plants. OGFC has been successfully produced in both batch and continuous mixing plants. When asphalt rubber is specified as the binder type, considerations must be accounted for as described in the "Asphalt Rubber Usage Guide" located on the Caltrans Website at:

http://www.dot.ca.gov/hq/esc/Translab/metspubs.htm.

Binder draindown is the migration of binder from the aggregate that results in dry spots and rich spots in the pavement. Dry spots can lead to raveling and rich spots can clog the open void structure and reduce the safety benefits of OGFC. OGFC mix temperatures that are above the specified temperature limits will cause binder draindown.

3.2 STORAGE

With the potential for binder draindown, the OGFC mix should not be stored in silos for more than two hours. When OGFC is stored in silos, it is essential that the mix be observed to assure that noticeable draindown does not occur.

3.3 TRANSPORTATION

Binder draindown may occur while transporting the OGFC mixture from the plant to the project site. If this occurs, asphalt may form a puddle in the bottom of the truck and cause a rich spot in the pavement underneath the truck after the mix is unloaded.

During transport of OGFC, contractors should use best management practices to minimize heat loss and protect the asphalt mix from the weather. These may include tarping the loads, selecting haul routes to minimize travel times, utilizing material transfer devices, dumping directly into the paver hopper, etc. For projects with long haul times, the use of polymer modified binder should be considered to allow for higher mixing temperatures at the plant.

Only non-petroleum type release agent should be used on truck beds for cleaning. Petroleum materials, such as diesel, will soften the mix and accelerate the deterioration of pavement.

3.4 PLACEMENT

The OGFC mixture may look rich during placement. This is due to a greater asphalt binder film thickness and lack of fine aggregate. The rich look is normal.

The following are issues associated with placement of OGFC.

3.4.1 *Tracking and Release to Traffic*

Most OGFC sets up quickly. However, to allow traffic on RAC-O and RAC-O-HB pavements before the rubberized material has cured and to reduce its tackiness, sand can be applied at a rate of 1 lb/yd^2 to 2 lb/yd^2.

Lime water should not be used to cool RAC-O and RAC-O-HB pavements because there are environmental concerns with the use of lime water.

3.4.2 *Tack Coat*

To ensure proper bonding between layers, adhere to the "Tack Coat Guidelines" that are located on the following Caltrans Website:

http://www.dot.ca.gov/hq/construc/cpb/cpb03-1attach.

3.4.3 *Construction Considerations*

Table 1, "OGFC Placement Temperatures," briefly describes best practices to consider when placing OGFC.

3.4.4 *Temperature*

Temperature is an important consideration during OGFC construction. The open void structure and relatively thin lift of OGFC makes it sensitive to temperature changes and causes it to lose temperature faster than DGAC. OGFC should not be placed in cold weather as this has led to several failures attributed to loss of bond between OGFC and the existing pavement surface and raveling. It is important that the temperature limits specified in the Standard Specifications and SSPs are adhered to during construction.

3.4.5 *Wind*

In addition to atmospheric temperature, consideration should be given to the speed of wind. During placement, wind may reduce temperature of the existing pavement and that of the OGFC mixture. In some cases, paving may need to be suspended if wind causes the OGFC mix to cool too quickly and interferes with compaction.

3.4.6 *Raking*

Raking should be very limited due to the coarse aggregate gradation and temperature sensitivity of OGFC. The coarse gradation makes it virtually impossible to feather OGFC. Raking or handwork can lead to segregation and premature raveling.

3.4.7 *Joints and Conforms*

Transverse joints are difficult to build in OGFC pavements. As a result, transverse joints should be butted or avoided by continuous paving.

Longitudinal joints are made in a similar manner as DGAC pavements.

Where OGFC conforms to existing DGAC pavement, consideration should be given to existing cross slopes. It is important to not impede drainage and allow OGFC pavements to properly drain.

OGFC is virtually impossible to feather at conforms; therefore, a small lip or bump may be created. Some Caltrans districts have success in grinding the bump at the conform several days after the OGFC was placed. Waiting a few days allows time for the OGFC to harden and prevents spalling and raveling while grinding.

3.4.8 *Rolling*

There are no density specifications for OGFC mixtures. Compaction is achieved by "method specification." The normal procedure for rolling is to make two complete coverages over the surface with a static steel wheel roller. Vibratory and pneumatic-tired rollers should not be used on OGFC pavements. The vibratory rollers degrade the aggregate and pneumatic-tired rollers tend to pick up asphalt, especially when polymer modified and asphalt rubber modified binders are used. The kneading action of the pneumatic-tired rollers also tends to close the voids in the surface of the OGFC, which does not allow for good drainage.

Follow the rolling requirements in the Standard Specifications and observe the rolling temperatures specified in Table 2, "OGFC Temperature Limits."

3.4.9 *Shoulder Backing*

Shoulder backing, if required, should be placed in accordance with SSP 19-720 and the

Pavement Tech Notes on "Shoulder Backing" located on the Internet at:

> http://www.dot.ca.gov/hq/oppd/pavement/guidance/ShoulderBackingGuideline-6-8-04.pdf.

3.4.10 *Dikes, Curbs and Gutters*

It is recommended to place all 'new' asphalt concrete dikes before placing OGFC. OGFC can then be placed up to the new dikes. Otherwise, the dikes will be placed over OGFC, which defeats the purpose of having dikes. Hydraulic design should consider the possible reduced height of curb and limited capacity caused by the adjoining OGFC when sizing and locating new drainage features.

It is acceptable to place OGFC up to 'existing' dikes before overlaying the existing dikes with new dikes.

It is recommended to place OGFC above the flow line of a gutter to allow for nonrestrictive and unimpeded flow of water. Improper placement of OGFC will prevent proper drainage. Water held within the OGFC could saturate the structural section and accelerate pavement deterioration.

3.4.11 *Smoothness*

For new construction, smoothness profiling should be conducted on the underlying pavement before the OGFC lift is constructed. **Corrections for smoothness should be completed prior to the construction of the OGFC surface!**

For maintenance and rehabilitation overlays, smoothness requirements should be met prior to placing OGFC. Placing OGFC should not be considered as an "opportunity" to improve smoothness.

For smoothness requirements at joints, the normal straightedge should apply to the OGFC lift. Except for correcting minor inadequacy in smoothness at the joints or bridge approaches/departures, grinding of OGFC should not be allowed. Grinding can plug the voids and interfere with drainage. Grinding can also make a thin lift of OGFC even thinner increasing the chances of fatigue cracking and raveling.

3.4.12 *Acceptance*

The acceptance tests for OGFC is essentially the same as that for DGAC. The primary difference is that there are no density requirements. The required tests for OGFC include aggregate gradation and asphalt content.

Anticipated Atmospheric Temperature	**Best Practices**
In General	• Follow the requirements in the Standard Specifications and SSPs. • Continuously monitor temperature and wind. • Ensure that a tack coat is applied uniformly and at the proper rate (reference the "Tack Coat Guidelines.") • Compaction of the OGFC pavement is complete after 2 complete coverages of the roller. • Stop operations if the critical temperatures* stated in Table 2 cannot be met.
T > 70°F	• For OGFC with conventional asphalt binder, complete rolling before the temperature of the OGFC reaches 195°F. • For OGFC with polymer modified binder, complete rolling before the temperature of the OGFC drops below 250°F. • For OGFC with asphalt rubber binder, complete the first coverage of the initial or breakdown compaction when the temperature of the OGFC is greater than 275°F. Complete breakdown compaction before the temperature of the OGFC drops below 250°F.
55°F < T ≤ 70°F	• For OGFC with conventional asphalt binder, complete rolling before pavement temperature reaches 220°F. • For OGFC with polymer modified binder, complete before the temperature of the OGFC drops below 250°F. • For OGFC with asphalt rubber binder, complete the first coverage of the initial or breakdown compaction when the temperature of the OGFC is greater than 280°F. Complete breakdown compaction before the temperature of the OGFC drops below 260°F.
45°F ≤ T ≤ 55°F	• Polymer modified binders must be used. • For OGFC with polymer modified binder, complete rolling before the temperature of the OGFC drops below 250°F.
T < 45°F	• OGFC should not be placed.

* Critical temperatures are the minimum atmospheric temperature, minimum pavement temperature, maximum aggregate temperature at plant, and the mix laydown temperature range.

TABLE 1: OGFC PLACEMENT TEMPERATURES

Type of OGFC	Minimum Atmospheric Temperature	Minimum Pavement Temperature	Maximum Aggregate Temperature at Hot Mix Plant	Recommended Minimum Breakdown Rolling Temperature	Recommended Minimum Finishing Rolling Temperature
Conventional (Normal)	70°F	*	275°F	N/A	195°F
Conventional (Cold Temperature)	55°F	*	275°F	N/A	220°F
PBA	45°F	**	325°F	N/A	250°F
Asphalt Rubber (Normal)	65°F	65°F	325°F	275°F	250°F
Asphalt Rubber (Cold Temperature)	55°F-65°F	55°F	325°F	280°F	260°F

* 60°F Minimum for bridge decks only. Requires permission from Headquarters Structures Design.
** 50°F Minimum for bridge decks only. Requires permission from Headquarters Structures Design.

TABLE 2: OGFC TEMPERATURE LIMITS

4.0 MAINTENANCE OF OPEN GRADED FRICTION COURSE

OGFC overlays may exhibit the following distress modes:

- Shear failures in high stress areas.
- Cracking due to fatigue.
- Cracking due to reflection from below.
- Raveling due to oxidation and hardening of the binder.
- Raveling due to softened binder from oil and fuel drippings.
- Raveling due to lack of compaction or low asphalt content.
- Delamination due to improper tack coat application.
- Clogging of voids from mud, sand, etc., causing loss of permeability (a clogged OGFC still drains better than DGAC).
- Rich and dry spots due to draindown of binder during transportation and placement.

Proper construction practices, selection of the correct binder, mix design, and job selection will help to minimize these distresses. The performance of OGFC is based on maintaining proper high void structure.

At this time, only removal and replacement is allowed for repairing a failed or aged OGFC.

Permeability must be maintained to ensure water flow is unimpeded**.** Maintenance activities on roadways surfaced with OGFC should avoid obstructing the lateral flow of water through the OGFC. These activities may include crack sealing or patching a small failed area with DGAG, thus creating a dam where water may be retained or stored and contribute to further failure of the OGFC surfacing. When large areas of patching are involved, OGFC should be replaced with OGFC.

OGFC has different thermal and icing properties compared to DGAC. Thermal conductivity is up to 70% less according to the National Asphalt Pavement Association (NAPA). As a result, ice and frost will accumulate faster and last longer on OGFC than DGAC. This is important for Maintenance workers to know, since this may alter the winter maintenance regimen as compared to DGAC. In addition, OGFC may require more extensive de-icing measures than DGAC due to the openness and quick draining of de-icing agents in OGFC.

Other related Maintenance issues with OGFC should be referred to the most current Maintenance Technical Advisory Guide located on the Caltrans Website at http://www.dot.ca.gov/hq/maint/mtag/ch8_maint_overlays.pdf